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The effect of dielectric permittivity on radiation characteristics of axially feed rectangular

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ABSTRACT: **Selection of proper substrate material is prime important task in microstrip patch antenna design. Because the limitations of micro strip antenna such as low gain, low efficiency and high return loss can overcome by selecting proper substrate materials, because permittivity of substrate is critical parameter in controlling band width, efficiency, and radiation pattern of patch antenna. The substrate materials have two basic properties such as dielectric constant and loss tangent. Present paper comprehensive study of various dielectric materials and its effect on radiation characteristics of rectangular patch antenna such as resonance frequency, bandwidth, gain, return loss, input impedance, radiation pattern, and current distributions are investigated. The dielectric materials selected here having zero loss tangent.**

Keywords: dielectric constant, patch, loss tangent

I. INTRODUCTION

The Substrates used in microstrip antenna is primarily provide mechanical strength to antenna, the dielectric medium allows surface waves to propagate through it which will extract some part of total power available for radiation which degrades the electrical properties of antenna. The cost of antenna design is also effected by dielectric material, hence it require intelligent decision while selecting substrate. Generally a dielectric substrate is defined by its two prime parameters one is its permittivity (It describes the materials with high polarizability) and another is loss tangent (It explains the dissipation of electromagnetic energy), $\varepsilon=\varepsilon_r\varepsilon_0(1\text{-}J\tan\delta)$. for loss less materials there is no loss tangent ($\tan\delta=0$) the permittivity is real and is $\varepsilon=\varepsilon_r\varepsilon_0$ In present paper rectangular micro strip antenna in its simplest form consisting of sandwich of two conducting layers separated by single thin dielectric substrate is considered, where lower conductor function as ground plane and upper conductor function as radiator. Larger ground plane gives better performance but makes the antenna size bigger. This is excited with coaxial feed. At resonate frequency of 2.0420GHz. The frequency bandwidth of a micro strip patch antenna depends primarily on both the thickness and dielectric permittivity of substrate. A thick substrate with low dielectric permittivity can increase the band width of printed patch. If the thickness of substrate increases create 1) difficulty in integration of antenna with other microwave circuits, 2) surface wave propagation and the large inductive image part of input impedance of

antenna which makes its resonance unfeasible[1]-[5]. Hence a reasonable band width of 1.56mm used in present project common for simulation all substrates.

II. MICROSTRIP PATCH ANTENNA DESIGN

The rectangular patch antenna consists of metalized pattern over a thin microstrip substrate. The back surface of substrate is ground plane. The length of patch (L) is about $\lambda_g/2$ (λ_g is effective wave length) and substrate height(h) is of order of $\lambda_g/20$.Due to very small space between radiating element and ground plane main power is radiated towards broad side. The fringing fields effectively increase the length(ΔL) of patch need to be accounted in determine resonance frequency [1].

The most commonly used design equations of antenna

a) Effective dielectric constant

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}}$$

b) Length extension is

$$\Delta L = 0.412h\frac{\left(\varepsilon_{reff} + 0.3\right)\left(\frac{W}{h} + 0.264\right)}{\left(\varepsilon_{reff} - 0.258\right)\left(\frac{W}{h} + 0.8\right)}$$

c) Effective Length

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{reff}}}$$

d) Actual length of patch

$$L = L_{eff} - 2\Delta L$$

e) Patch width

$$W = \frac{c}{2f_o\sqrt{\frac{(\varepsilon_r+1)}{2}}}$$

f) Ground plane dimensions

$$L_g = 6h + L$$

$$W_g = 6h + W$$

III. CO-AXIAL PROBE FEED

This is a common feed technique here outer conductor is connected to ground plane and the inner conductor of co-axial connector is extends through dielectric and soldered to patch. Inner conductor of co-axial cable transfers the power from strip line to microstrip antenna from slot in the ground plane. Placing of feed position is important in order to have best matching with input impedance. Here fees is applied at (0mm, 9.2mm). It provides narrow bandwidth performance and it is difficult to design for thick substrate.[1]

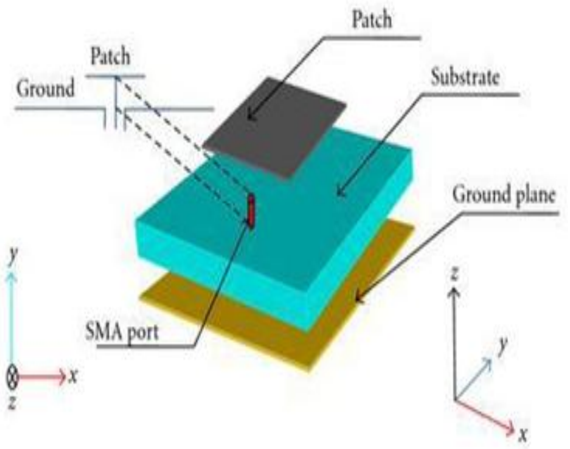


Fig 1: Coaxial Feed

IV **Dielectric Material Data**

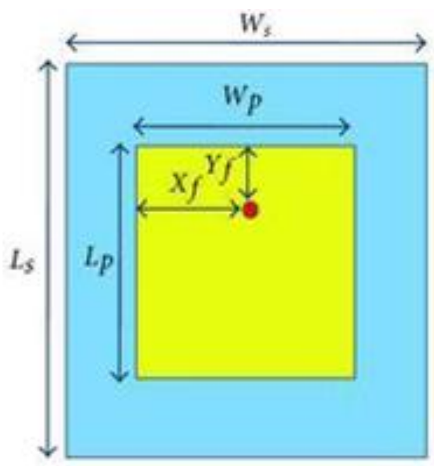
Present paper I have considered perfect dielectric materials listed below. Here I am saying perfect dielectric means loss less dielectric (Tanδ=0). Many authors investigated effect of substrate material on radiation characteristics but considered loss tangent values. My question here, how one can get genuine results when the dielectric material chosen contain losses. The following listed dielectric materials are considered in present paper

TABLE I
DIELECTRIC CONSTANT

Material Name	**Permittivity**	**Loss Tangent**
Air	1	0
Benzocyclobuten	2.6	0
Rubber	3	0
Polyimide Quartz	4	0

V **NUMERICAL DESIGN**

The proposed co-axial feed rectangular micro strip patch antenna operating at 2.0420GHz having physical dimensions of radiating patch length L=47.4mm along Y-axis, width W=56.5mm along X-axis (here width of patch is maintained higher than length because of wider operating band width). The co-axial feed is provided at 0mm, 9.2mm along X,Y-axis respectively. The substrate height is 1.56mm



F ig 2: Coaxial feed microstrip antenna

VI **SIMULATION SETUP**

By the availability latest simulation software, now a days it become very easy to implement our ideas or proposals insisted of directly stepping to real time implementation. Present project work of coaxial feed rectangular patch antenna was designed with above given specification in Ansoft HFSS software. And results of return loss, gain and band width were presented.

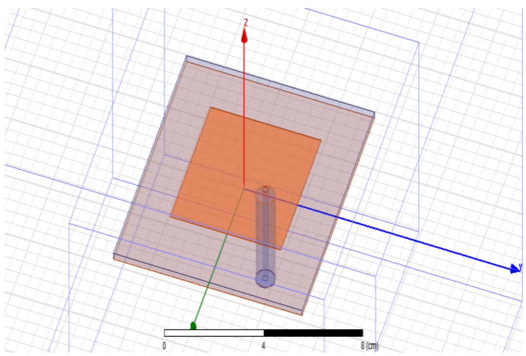


Fig 2: Simulated Antenna Model

VII RESULTS & DISCUSSION

A. Return loss

This is important to calculate the input and output of signal source. Because if load is mismatched the whole

power is not delivered to load and there is a return of power that is called loss, since this loss is returned hence is called return loss is $-20\log|\Gamma|$. Where Γ is reflection coefficient. The response of magnitude of S11 verses frequency curve clearly explains return loss

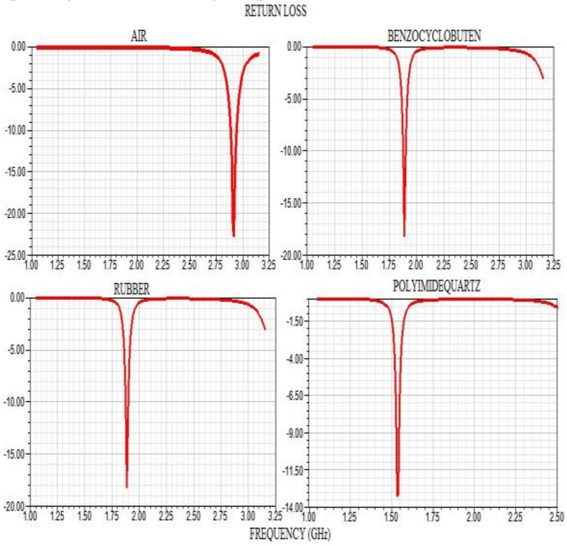


Fig 3: Return loss

The air dielectric has lower permittivity out of all when it placed between reflecting ground and radiating patch has given effective radiation patterns and very low return loss that indicates maximum amount of inputted power converted into electromagnetic waves very loss amount is reflected back. The Benzocyclobuten has a return loss of -18.1248 at the operating frequency of 1.8837GHz, Rubber has -18.1248 return loss at 1.8837GHz, (Since the permittivity of benzocyclobuten and rubber is very nearer hence there is not much difference obtained for observation), The polyimidequartz has -13.2234 return loss at 1.5309GHz . By observation we can conclude that as the increase of dielectric permittivity the return loss is increasing hence very less amount of power is forwarded to radiating element hence radiating characteristics can be degraded.

TABLE II
RETURN LOSS

Substrate	Return loss	Operating Frequency(GHz)
Air	-22.6449	2.9178
Benzocyulobuten	-18.1248	1.8837
Rubber	-18.1248	1.8837
Polyimidequartz	-13.2234	1.5309

B. *Gain*

Since antenna is a passive device the gain cannot be measured directly, test antenna radiations is compared with hypothetical isotropic antenna. Gain is a measure of power radiated per unit surface area by the test antenna in a given direction at an arbitrary distance, the obtained results are compared with the results of isotropic antenna. Gain explains figure of merit of antenna which combines antennas directivity and electrical efficiency

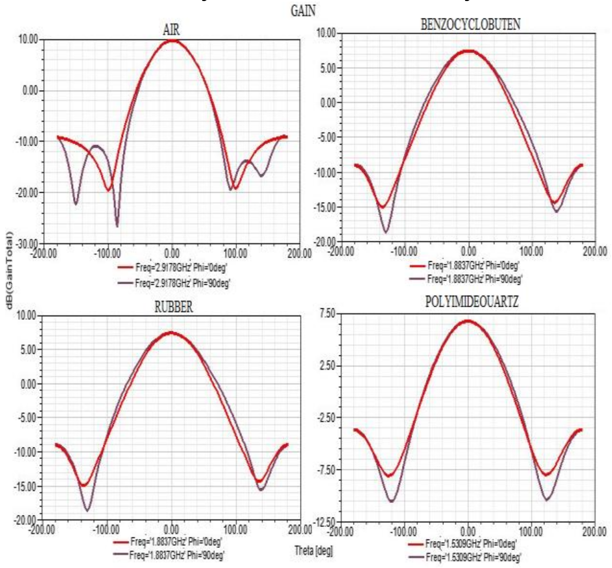


Fig 4:Gain in 2D

The gain is also high when lower dielectric materials are used between ground plane and radiating element. Present paper Air has higher gain 9.3 dB remaining benzocyclobuten, rubber and polyimidequartz has gain 5.5dB, 5.5dB and 4.7dB respectively.

C. *Radiation Pattern*

Radiation pattern is a graph which shows the variation of actual field strength of electromagnetic field at all the points equidistant from the antenna Radiation pattern graph (teta) directions here shown for clear understanding of patterns

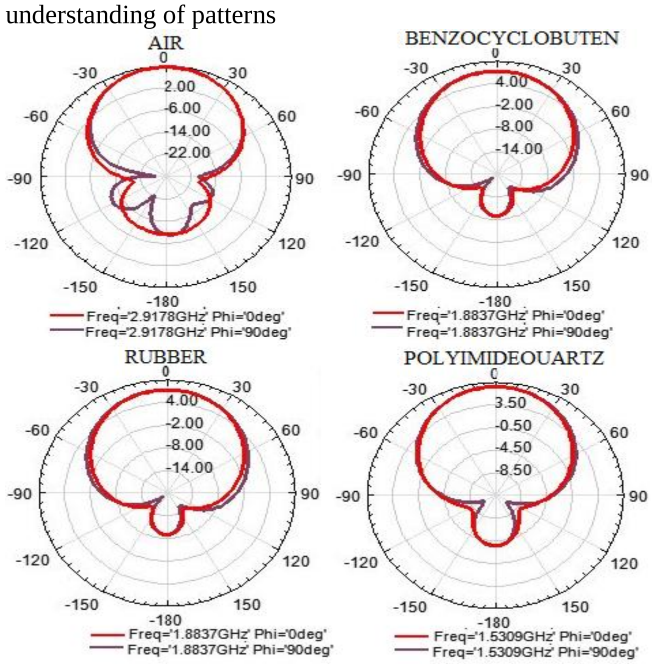
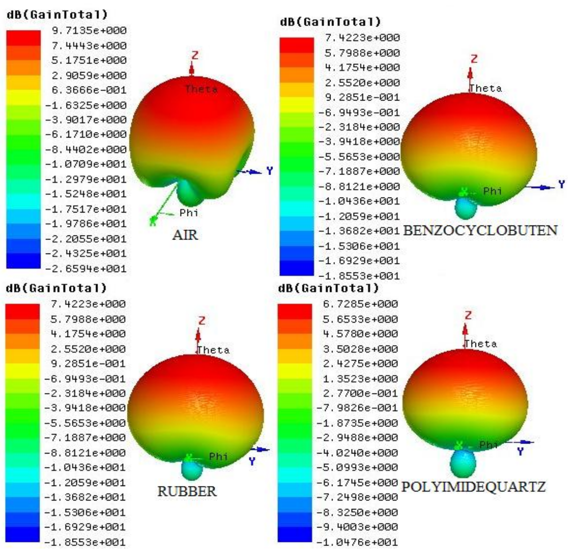


Fig 5: Radiation pattern

D. Gain



VIII ANTENNA PARAMETERS

TABE III
ANTENNA PARAMETERS

Parameter/ Substrate	Air	Benzocyclobuten	Rubber	Polymidequartz
Max U	0.007344 (W/Sr)	0.00428196 (W/Sr)	0.004282 (W/Sr)	0.00353393 (W/Sr)
Peak Directivity	9.30934	5.5124	5.5124	4.70551
Peak Gain	9.36549	5.5237	5.5237	4.70818
Peak Realized Gain	9.32019	5.4334	5.4334	4.48395
Radiated Power	0.00991365(W)	0.00976167(W)	0.0097617(W)	0.00943781(W)
Accepted Power	0.00985422(W)	0.0097417(W)	0.0097417	0.00943247(W)
Incident Power	0.00990212(W)	0.0099035(W)	0.0099035	0.00990416(W)
Radiation Efficiency	1.00603	1.00205	1.002	1.00057
FBR	78.6541	43.5728	43.573	10.8957

IV. CONCLUSION

By care full observation of antenna parameters table and radiation pattern diagrams we can conclude that the increment of substrate dielectric constant in antenna design, results degradation of performance characteristics. Antenna parameter table the gain, directivity radiation efficiency and FBR are degraded from air dielectric to polyimidequartz.

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